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THE PETROGRAPHICAL PROVINCE OF ESSEX COUNTY, MASS. I.

THE area of igneous rocks in Eastern Massachusetts, especially in Essex county, has been, as the late Geo. H. Williams said, "more discussed than any other similar region of the continent." But, while it is the subject of a considerable literature, no petrological study of the region has been made. A few investigators, notably Wadsworth and J. H. Sears, have described the rocks, but there has been little or no attempt to coördinate the results and to compare this region with other analogous petrographical provinces, although its resemblance to that of Norway has been noted by Rosenbusch, Brögger and others. It is with the aim of supplying this deficiency that these pages are written.

I have visited the region of Essex county several times and collected a large number of specimens from the various localities, so that my collections are fairly representative of the different types, and my knowledge of their occurrences and relationships sufficient to justify me in undertaking the present investigation. This paper will deal with the subject in a purely petrological way, since the general geological, structural and stratigraphical features are far too complex to be unraveled in occasional visits such as mine were. A number of occurrences of dike and other rocks which merit a more detailed description than is here possible will be published separately, probably, in the *American Journal of Science*.

I would express my sense of deep obligation to Mr. J. H. Sears, of Salem, who has made this region an object of study for many years and whose acquaintance with it is unequalled. He has been most cordial and liberal in giving me specimens which it would have been difficult for me to obtain otherwise, and has encouraged me most generously in undertaking the present investigation.

While the general geology of the region lies outside the scope of the present paper, yet it will be not amiss to give a sketch of its chief features. The igneous rocks of Essex county extend along the coast from Lynn to the New Hampshire line, and inland for a distance of about five to fifteen miles, covering an area of about 342 square miles. To the south igneous rocks of similar character, and probably genetically related, are met with in the Boston Basin, but this paper does not include them. In Essex county they form a long ridge "extending in a northeasterly direction until cut off by the sea. To the northwest and to the southeast of this extended axis we have rocks of a less crystalline character verging upward into distinctly sedimentary deposits."¹ The igneous rocks have broken through and are later than pre-Cambrian and Lower Cambrian strata, blocks of which, often highly metamorphosed, are met with at many points within the igneous area.² The igneous rocks are chiefly granites, quartz-syenites, syenites, nepheline-syenites, essexites, diorites and gabbros, cut by numerous dikes, and with later flows of rhyolite. According to Sears³ these are all pre-Carboniferous. A geological map of Essex county, prepared by Mr. Sears, and published by the Essex Institute in 1893, has lately (1897) been revised by him⁴ and will be referred to frequently.

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In the description of the rocks the ideas as to classification generally prevailing in this country will be followed, the age distinction being ignored, and the rocks grouped according to structure and chemical and mineralogical composition. The separation of the dike rocks is largely for convenience and involves no assumptions as to the question of the "Ganggesteine." A number of chemical analyses will be given, and the descrip-

¹ N. S. SHALER, 9th Ann. Rep. U. S. G. Surv., p. 542, 1889.

² J. H. SEARS, Bull. Essex Inst., Vol. XXII, 1890.

³ SEARS, Bull. Essex Inst. Vol. XXVII, p. 112, 1895.

⁴ Bull. Essex Inst., Vol. XXVI, 1894, and *ibid*, Vol. XXVII, 1895.

tions will be followed by a general discussion of the results and a comparison of this region with others of similar character.

Granite.—The rocks which belong in this class and which are the granites of Rosenbusch, have been described by Wadsworth,¹ Shaler² and Sears.³ They are very abundant in the region, covering large areas at Rockport, Gloucester, Manchester, Beverly, Essex and elsewhere, having a general northeast-southwest trend.

The specimens in my possession from these localities are all hornblende-granites containing more or less biotite. The structure is in general typically granitic, a porphyritic development of the feldspar being rare. They are quite coarse-grained, the texture being fairly uniform in the various specimens. Fine-grained forms are less abundant and occur on the borders, as will be described later. In color they are usually light mottled gray (Rockport, west Gloucester, Manchester), but often yellowish (Bay View, Eastern Point), or pink (Wolf Hill, Marblehead Neck), these last two being due to incipient decomposition. The granite of Bass Rock is darker and greenish, forming apparently a transition to the augite-quartz-syenite.

The quartz is often dark and smoky. The feldspars are of the usual light shades, with good cleavage, being salmon-colored only in the specimens from Wolf Hill. Hornblende and biotite are scattered not very abundantly through the mass in black irregular spots. These are the principal minerals seen with the naked eye, but at the quarries of Rockport and elsewhere a large number of accessories have been found, including danalite, fayalite, epidote, zircon, magnetite, apatite, fluorite, and others.

In the area about Rockport pegmatitic veins are not uncommon, made up of coarsely crystalline feldspar and quartz, the latter being occasionally amethystine. The granite, especially of Cape Ann, is largely split by joint planes, and also shows a strong tendency toward rifting. This has been investigated

¹ WADSWORTH, Proc. Bost. Soc. Nat. Hist. Vol. XIX, p. 311, 1878

² SHALER, 9th Ann. Rep. U. S. G. Surv., p. 605, 1889.

³ SEARS, Bull. Essex Inst., Vol. XXVI, 1894.

very fully by Shaler.¹ Judging from the evidence of strain revealed by the microscope the rifting (and possibly the jointing in part) is largely due to dynamic action subsequent to the consolidation of the mass.

In thin sections are seen the following minerals; orthoclase, albite, microcline, hornblende, glaucophane, biotite, pyroxene, magnetite, zircon, apatite, and allanite.

The quartz is highly xenomorphic, being usually interstitial. In some cases (Bass Rock, Rocky Neck at Gloucester) it also occurs in small rounded anhedral, scattered through feldspar areas. A brecciated structure at the borders of the larger quartzes is not rare, and is associated with an undulatory extinction. Mineral inclusions are few, and are only zircons. Gas and liquid inclusions, the latter carrying a movable bubble, are quite abundant though small, and occur in streaks.

The alkali-feldspars are varied and deserve more extended study than the scope of this paper allows. They are chiefly orthoclase and albite, which are almost always intergrown so as to form highly typical micropertthites and cryptopertthites. In general they are closely similar to those described by Brögger² and Ussing³ from Norway and Greenland syenitic rocks, and their figures would answer for forms seen here. Cryptopertthitic development is relatively scarce, the majority being perthitic on a fairly large scale. Microcline also is not rare, but less abundant than the preceding. This and the orthoclase are apparently rich in soda. The feldspars are apt to be rather cloudy and dusty with decomposition products, and they often show a brecciated border and undulatory extinction. Inclusions of apatite and zircon are rare. A very little albite-oligoclase is seen in a few sections, showing well-developed twinning lamellæ.

Hornblende, the chief ferromagnesian mineral, is usually xenomorphic, crystal planes being seldom seen. It is in gen-

¹ SHALER, 9th Ann. Rep. U. S. G. Surv., pp. 583-588, 602-605, 1889.

² W. C. BRÖGGER, Zeit. Kryst., Vol. XVI, pp. 521-560, 1890, Pls. XXII, XXIII

³ USSING, Medd. om Grönland, Vol. XIV, pp. 5-101, 1898, Pls. I, II, III.

eral olive-green and highly pleochroic; **c**=dark olive-green, **b**=dark greenish-brown, **a**=yellowish-green. The absorption is **c** > **b** > **a**. The extinction angle $c \wedge c$ is high, about 29° having been observed in sections cut nearly parallel to (010). In certain specimens, notably those from Eastern Point (Gloucester) and Magnolia, a bluish hornblende occurs not only as separate crystals, but as patches in the green hornblende, and is also found forming a fringe on the ends of large crystals of this mineral. This occurrence is somewhat analogous to that described by Cross¹ in a dike in Colorado, where he regards the blue hornblende as secondary. His dike was much decomposed, while these granites are quite fresh; but it seems probable that here also part of the blue hornblende is secondary. As will be seen later, they are quite common in the region, and in many cases are undoubtedly primary. Inclusions in hornblende are not abundant, a few grains of magnetite, allanite, zircon, and apatite having been seen. The green hornblende often yields a secondary brown biotite on decomposition.

Biotite is a very common constituent, the greater part being primary. The granite near Manchester, represented by specimens from several quarries, is essentially a biotite-granite, hornblende being absent. In the majority of occurrences, however, the biotite accompanies hornblende, and is present in less amount. Two varieties are found. One is very pale green, with rather weak pleochroism, the colors being almost colorless and delicate apple-green. This is probably to be referred to the cryophyllite discovered by Cooke,² and investigated by Clarke and Riggs.³ The other, which is more abundant, is darker greenish-gray, and shows stronger pleochroism; a deep, almost opaque, greenish-gray and a pale olive-green. Sections parallel to the base show in convergent light a marked opening of the optic axes. This biotite is referred to lepidomelane (annite), but Clarke's researches have shown that several varieties exist.

¹ CROSS, *Am. J. Sci.*, Vol. XXIX, p. 359, 1890.

² J. P. COOKE, *Am. J. Sci.* (2), Vol. XLIII, p. 217, 1867.

³ F. W. CLARKE, *Am. J. Sci.* (3), Vol. XXXII, p. 358, 1886.

Both biotites are notable for their poverty in MgO, which will be discussed later. They frequently show signs of alteration, accompanied by the development of magnetite grains, and their laminae are often bent and distorted.

Secondary biotite occurs in most of the less fresh specimens, of a chestnut-brown color and highly pleochroic. It forms small flakes arranged perpendicular to or in fan-shaped aggregates along the edges of hornblende crystals, of which it is an alteration product. In the granite from the east side of Wolf Hill (Gloucester) are seen small clusters of small biotite flakes of an olive-green color and independent of hornblende, which are probably primary.

Pyroxene occurs in a few of the granites, most abundant in that of Marblehead Neck, though always in smaller amounts than the hornblende or biotite. It is a colorless diopside in stout, columnar, rounded crystals, and shows no noteworthy peculiarity. Occasionally, as at Trumbull's quarry, West Gloucester, it seems to be derived from hornblende, analogously to the often-observed "magmatic" alteration of hornblende in eruptive rocks. In some sections of granites which are not quite fresh the pyroxene is uralitized to some extent.

Magnetite is present in most of the granites, but very sporadically and in extremely small amount. Zircon and apatite are likewise present in most of the specimens, the former being the more common, while apatite is wholly absent in many.

Allanite occurs in granite from a quarry near the Lighthouse on Eastern Point and in that from Marblehead Neck. In the former it is included in hornblende, in the latter in biotite. The sections are rather long, with pointed ends, and the extinctions, either parallel or at angles up to 36° , show that the habit is tabular parallel to a (100). The color is deep brown, with strong pleochroism; **a**=light yellowish-brown, **b**=chestnut-brown, **c**=very dark brown; $c > b > a$. A zonal structure is common, the borders being lighter than the interior. Allanite was first observed in Essex county by D. M. Balch¹ in

¹ Am. J. Sci. (2), Vol. XXIII, p. 348, 1862.

1862 in the granite of Swampscott, was reported from several places in Maine and Massachusetts by Iddings and Cross,¹ while Sears² has added a number of localities to the list.

A small grain of pink fluorite was seen in the granite from Squam Light, and colorless grains in that from Pigeon Hill quarry, Cape Ann. I could identify no danalite, which Shaler speaks of as rare and resembling garnet in thin sections.

For chemical analysis a typical fresh specimen was chosen from the large pit of the Rockport Granite Co.'s quarry, a hornblende-biotite-granite; sp. gr. 2.618 at 18° C. There is given for comparison an analysis already published³ of the riebeckite-granite of Quincy, described by T. G. White.⁴

	I	II		I	II
SiO ₂ - - -	77.61	73.93	BaO - - -	....	none
TiO ₂ - - -	0.25	0.18	Na ₂ O - - -	3.80	4.66
Al ₂ O ₃ - - -	11.94	12.29	K ₂ O - - -	4.98	4.63
Fe ₂ O ₃ - - -	0.55	2.91	H ₂ O(110°-) -	trace	....
FeO - - -	0.87	1.55	H ₂ O(110°-) -	0.23	0.41
MnO - - -	trace	trace	P ₂ O ₅ - - -	....	....
MgO - - -	trace	0.04			
CaO - - -	0.31	0.31	Sp. Gr.	100.54	100.91

I Hornblende-Granite. Rockport Cape Ann, Anal. H. S. WASHINGTON.

II Riebeckite-Granite. Quincy Blue Hills, Anal. H. S. WASHINGTON.

The analysis of the Rockport granite is a typical one, fairly rich in potash, but low in lime and iron oxides. It resembles that of the Quincy granite, but the latter is lower in silica and higher in iron oxides. Although the composition of the hornblende is unknown, yet as its amount is small, the mineral composition can be approximately calculated as below in Ia, the biotite being assumed to have the composition (K₂H₄Fe₄) Al₂(SiO₄)₅ as given by Clarke from an analysis by Riggs.⁵ The composition of the Quincy granite calculated as already published is given in IIa.

¹ IDDINGS and CROSS, Am. J. Sci. (3), Vol. XXX, p. 108, 1885.

² SEARS, Bull. Essex Inst., Vol. XXVI, p. 189, 1894.

³ H. S. WASHINGTON, Am. Jour. Sci. (4), Vol. VI, p. 181, 1898.

⁴ T. G. WHITE, Proc. Bost. Soc. Nat. Hist., Vol. XXVIII, p. 128, 1897.

⁵ CLARKE, Am. Jour. Sci. (3), Vol. XXXII, p. 360, 1886.

	Ia	IIa		Ia	IIa
Quartz, - -	35.5	30.2	Hornblende, -	2.0	....
Orthoclase, - -	28.2	27.2	Riebeckite, - -	....	12.3
Albite, - -	32.0	27.7	Glaucophane, -	....	2.0
Anorthite, - -	0.5	....	Accessories, - -	0.5	0.6
Biotite, - -	1.3	....			

Micrographic granite.—On reference to Sear's geological map of Essex county it will be seen that surrounding the granite areas and forming a zone between them and the areas of augite-syenite and diorite is a belt of micrographic granite. I have only a few specimens which represent this facies, the best being from Eastern Point, Gloucester, and from near Coy's Pond, Beverly, which were kindly given me by Mr. Sears. These closely resemble the granites, but are dark reddish-brown, finer grained and with less quartz visible. In thin sections they show much the same features as the granites proper. The minerals are the same, but quartz is less abundant. The difference is mainly in structure. In these rocks a micrographic intergrowth of feldspar and quartz is extremely common. The quartz here appears as small rounded spots extinguishing simultaneously in patches in the large feldspars. A similar micrographic structure is described by W. D. Matthew¹ in soda-granite from St. John, N. B. He states, however, that here this structure is best developed in the central parts of the mass and is lost at the edges.

In regard to the composition, while no analysis was made on account of the decomposed condition of the specimens, yet it seems probable, judging from the microscopical examination, that these micrographic granites are intermediate in composition between the granite proper and the augite-syenite, with a silica content of about 70.

Enclosures in granite.—In the granites of Essex county are found in abundance streaks (*Schlieren*) and rounded rock masses of darker color and of finer grain than the surrounding rock, which are also common in granite areas elsewhere. They show

¹ W. D. MATTHEW, Trans. N. Y. Acad. Sci., Vol. XIV, p. 205, 1895.

an evenly granular, granitic structure, varying in texture from moderately to very fine grained and compact. In color they vary correspondingly from light to very dark gray the most compact forms being the darkest. To the naked eye they show the same minerals as the granite, but the ferromagnesian constituents are more abundant. The contact with the surrounding granite is nearly always sharp and clear.

Under the microscope the same essential minerals are seen as in the granite and their habit is much the same, except that all is on a smaller scale. The alkali feldspars are quite similar, hornblende and biotite occur in all cases, the former being generally more abundant. It is usually green and only occasionally shows a bluish hue. In certain rather dark masses from the Pigeon Hill quarry, near Rockport, there is found a peculiar hornblende which occurs in bundles of long slender rods. In color it varies from colorless to pale bluish-gray, the latter shows brilliant polarization colors especially on the edges, and extinguishes obliquely, $c \wedge c$ being about 15° . The pleochroism is rather strong, $\perp c$ colorless or pale yellow, $\parallel c$ bluish or deeper yellow-gray, though occasionally it shows no pleochroism. It is apparently a variety of glaucophane. The biotite is also like that of the granites. It is sometimes secondary about hornblende, and in one specimen from Bay View it occurs about magnetite in brown flakes arranged radially. Colorless diopside is not abundant and often shows signs of alteration. Magnetite, while not abundant, is yet more common than in the granite. Zircon is common and in specimens from Pigeon Hill quarry forms well shaped but corroded crystals of considerable size, one being 1.5 mm long. Apatite is present as an accessory, but allanite was not observed.

SiO ₂ - - -	67.35	MgO - - -	0.03
TiO ₂ - - -	0.60	CaO - - -	0.55
Al ₂ O ₃ - - -	15.05	Na ₂ O - - -	4.42
Fe ₂ O ₃ - - -	1.23	K ₂ O - - -	6.08
FeO - - -	4.76	H ₂ O (110°-) -	0.16
MnO - - -	0.05	H ₂ O (110°+) -	0.17
			100.45

An analysis was made of a rather dark, fine-grained specimen from Pigeon Hill quarry, whose sp. gr. was 2.69 at 17° C. It is notably less siliceous than the granite, contains more iron and lime and higher alkalis, though the ratio of soda to potash remains about the same. From its analogy with the analysis of rocks described below it may be called a quartz-syenite. Owing to the uncertainty of the composition of the hornblende and biotite no exact calculation of the mineralogical composition is possible. A rough estimate gives albite 36, orthoclase 33, quartz 16, hornblende and biotite about 12, and magnetite, etc., 3 per cent.

Akerite (augitic quartz-syenite).—The rocks belonging in this class were first noticed by Wadsworth¹ in 1885 and were later described more in detail by Sears.² Rosenbusch³ has expressed the opinion that these are related to the akerite type of syenites, a keen observation which my study of the rocks fully confirms. These rocks are found chiefly in the eastern part of Essex county, in Essex, Beverly, Manchester, Gloucester, and on Cape Ann. They lie between or around the granite areas, are connected with nepheline-syenites on the south, and have a general north-east-southwest trend. They appear to be almost as abundant as the granites.

Although Sears speaks of the megascopic characters as being extremely variable yet all the specimens collected by myself, as well as those given me by him, are fairly uniform. These show a granitic structure and are usually coarse-grained. The color even of the freshest specimens is greenish, which varies in shade from a dark greenish black to a light shade of greenish gray. They weather to a reddish color as Sears observed. The bulk of the rock is composed of feldspar which is of a deep greenish color, often fresh and with glistening cleavage surfaces, at other times dull and waxy. Quartz grains are present in varying amount, some specimens showing considerable while others

¹ WADSWORTH, Geol. Mag., 1885, p. 207.

² SEARS, Bull. Essex Inst., Vol. XXIV, 1892, and Vol. XXV, 1893.

³ ROSENBUSCH, Mikr. Phys., Vol. II, p. 127, 1896.

contain very little, but it is never wholly absent. Black spots of augite are abundant and magnetite is seen here and there.

The microscope reveals the presence of the following minerals: quartz, alkali feldspar, diopside, hornblende, biotite, magnetite, apatite, and titanite. Quartz is not very abundant and is the last product of crystallization, occupying the interstices between the other minerals. It is undoubtedly primary, but the extinction is very often undulatory. The feldspars are mainly microperthitic intergrowths of orthoclase and albite, and resemble closely those of the granite. Microcline is rare. The feldspars are highly irregular as a rule, though some crystal outlines are seen against interstitial quartz. The boundaries between the adjacent crystals are generally zigzag or brecciated, indicating that the mass has been subjected to stresses. Some small albites show beautifully fine and clear twinning lamellæ. As they occur in such brecciated areas they may be supposed to be secondary. The feldspars very commonly show signs of alteration which is evidenced by a cloudy appearance, or when the crystal substance is clear by the cleavage lines and cracks being filled with a greenish decomposition product, the exact nature of which could not be determined.

The pyroxene occurs in scattered crystals of irregular outline. It is nearly colorless or a pale greenish-gray, without pleochronism but with high extinction angles. It is not infrequently uralitized on the edges, and carries inclusions of magnetite, apatite, and titanite. Primary hornblende of deep green or brownish colors is common in some specimens, notably in those from Poorhouse Hill, Beverly, and Cape Pond, Rockport. This is also intergrown with the pyroxene in parallel positions. Biotite is extremely rare or entirely wanting in these rocks, and when present is almost certainly secondary. Magnetite and apatite, occasionally in very long needles, are more common than in the granite. Zircon is present but is less abundant. Colorless titanite is quite common, usually in almost square sections with oblique extinctions. No nepheline was to be found in any of my sections, although Sears notes its presence. Its occur-

rence with quartz would be certainly very anomalous. Aegirite also, mentioned by Sears, was wanting in the material examined by me.

An analysis was made of a nearly fresh, typical specimen collected from a newly blasted mass on Prospect street, Gloucester. It is neither extremely light nor extremely dark in color, and seems to be an average sample of these rocks. Its sp. gr. was 2.612 at 17° C. For comparison there is given in II the analysis of an acid akerite from Norway.

				I	II					I	II
SiO ₂	-	-	-	66.60	66.13	MgO	-	-	-	0.36	0.04
TiO ₂	-	-	-	0.76	0.74	CaO	-	-	-	2.21	0.81
Al ₂ O ₃	-	-	-	15.05	17.40	BaO	-	-	-	none	....
Fe ₂ O ₃	-	-	-	1.07	2.19	Na ₂ O	-	-	-	4.03	5.28
FeO	-	-	-	4.42	....	K ₂ O	-	-	-	5.42	5.60
MnO	-	-	-	trace	0.13	H ₂ O	-	-	-	0.41	1.22
										100.33	99.54

I Akerite. Prospect street, Gloucester. H. S. WASHINGTON, anal.

II Akerite (porphyritic). Between Thinghoid and Fjelebua, Norway. MAUZELIUS, anal. BRÖGGER, Zeit. Kryst., Vol. XVI, p. 46, 1890.

It will be seen that this analysis, which closely resembles that of the enclosure in granite, except the higher lime, is essentially that of a basic granite or an acid syenite. In this case I adopt Brögger's scheme of classification,¹ and consider that the limit between the syenites and the granites lies at the silica content of the prevailing feldspars, which are here orthoclase with about 66 per cent. and albite with about 68. These rocks, therefore, I would class with the quartz-bearing augite-syenites, in accordance with Wadsworth, Sears and Rosenbusch.

That the rock belongs to an alkali magma is evident from its high alkali content ($K_2O + Na_2O = 9.45$), and its close parallelism with the *more acid* of Brögger's akerites is shown by comparison with the analysis in II. It must be noted, however, that this is an extreme type, and that the akerites as a group are more basic. Probably some of the darker and presumably

¹ BRÖGGER, Zeit. Kryst., Vol. XVI, p. 55, note, 1890.

more basic specimens, such as one from the railroad cut just north of the Manchester station, would correspond to them. The rather high lime is to be noted, but this is used up in the formation of pyroxene, leaving none for lime-soda feldspar, which, as the microscope shows, is not present.

Nordmarkite (*mica-hornblende-quartz-syenite*).— In Shaler's geological map of Cape Ann¹ there is indicated on both sides of Squam River an area of igneous rock, which is called diorite. Sears,² after a careful study of all the occurrences, came to the conclusion that they are not diorite but "phases of the augite-syenite rock," an opinion in which I concur. These rocks are far more limited in their distribution than the preceding, being found chiefly in Shaler's "diorite" area in West Gloucester and along the Squam River. I have specimens also from Hospital Point, Beverly, and from Salem Neck. They are light-gray fine-grained rocks, of granitic structure, looking like fine-grained diorite, composed of a white mass of feldspar, with subordinate quartz, thickly sprinkled with black specks of biotite and hornblende. The specimens from Hospital Point and Salem Neck are porphyritic through the presence of rectangular feldspar phenocrysts, from five to ten millimeters in length, and a few small quartzes.

They show under the microscope a granitic structure, though the quartz is less apt to be interstitial and usually forms small rounded spots in the feldspars, but is not pegmatitic as in the micrographic granite. The feldspars are alkali-feldspars, but do not show much tendency to microperthitic intergrowth. For the most part they are orthoclase or soda-orthoclase in simple crystals or Carlsbad twins. Albite is present in smaller amount, showing fine twinning lamellæ, with the extinctions proper to that mineral. In the specimens from Shaler's "diorite" area biotite is almost the only colored constituent. It forms small brown or greenish-brown, strongly pleochroic flakes, which are only rarely altered at the borders with development of magnetite grains. A

¹ SHALER, 9th Ann. Rep. U. S. G. Surv., Pl. LXXVII, 1889.

² SEARS, Bull. Essex Inst., Vol. XXV, 1893.

green hornblende is rare in these specimens and pyroxene seems to be entirely wanting. Magnetite, apatite and zircon are present in small amount. Aegirite, spoken of by Sears as often present, was not seen by me.

The specimens from Hospital Point and Salem Neck resemble these as far as the quartz and feldspars go, though these are finer in grain and microcline is more abundant. The biotite is also identical. A fresh, primary, greenish-gray pleochroic hornblende is abundant. Both minerals are much corroded. Magnetite and apatite are more abundant, zircon in about the same amount. These rocks are apparently transition forms toward a more basic variety, represented by specimens from Concord street, West Gloucester and from several points south of Shaler's area. The latter are darker in color, due to greater abundance of biotite and hornblende. They are like those just described in thin section except that there is less quartz, and hornblende and biotite are more abundant, the former predominating. While no plagioclase or nepheline was seen, they seem to be connecting phases with the diorites and essexites of the region near them.

For the analysis representing these quartz-syenites a specimen was chosen from the west end of Wolf Hill, northwest of Gloucester, which, although not far from the granite, was fresh and seemed to be representative of the rocks of Shaler's area. For comparison is given an analysis of nordmarkite from Norway.

	I	II		I	II
SiO ₂ - - -	68.36	64.02	CaO - - -	1.85	1.00
TiO ₂ - - -	trace	0.62	BaO - - -	....	....
Al ₂ O ₃ - - -	16.58	17.92	Na ₂ O - - -	3.97	6.67
Fe ₂ O ₃ - - -	0.90	0.96	K ₂ O - - -	5.27	6.08
FeO - - -	3.24	2.08	H ₂ O(110° -) -	0.18	....
MnO - - -	trace	0.23	H ₂ O(110° +) -	0.17	1.18
MgO - - -	0.45	0.59			
				100.97	101.37

I Nordmarkite, Wolf Hill, Gloucester. H. S. WASHINGTON anal.

II Nordmarkite, Tonsenaas, North of Christiania. JANNASCH anal. BRÖGGER, Zeit. Kryst., Vol. XVI, p. 54, 1890.

The close resemblance of this analysis to those of the granite enclosure and the akerite is evident, the main difference being in the silica, while, like the akerite, it is richer in CaO and MgO than the enclosure. It also closely resembles the analysis of nordmarkite from the Christiania region, although rather more acid and with less alkalies. Since it corresponds to these in mineral composition the name of nordmarkite is justified, especially as the akerites are a more basic group, while the nordmarkites are essentially more acid in their characters and affinities. It may be noted *en passant* that here also, as in so many cases elsewhere, we meet with biotite and hornblende occurring in the more acid, while pyroxene occurs in the more basic, members of the same series.

Nepheline-syenite. — The rocks belonging here, first noticed by Streeter, have been described by several petrographers, of whom may be mentioned Kimball,¹ Wadsworth,² Sears³ and Rosenbusch.⁴ They are not abundant in the region and are confined to an area along the coast about eight miles long and much less wide, extending from Salem Neck to Gale's Point, Manchester, and including the islands in and near Salem Harbor.

These rocks, as is usual, are prone to variation so that there is much variety among the specimens, even from the small area of Salem Neck. Structurally they may be divided into two groups, a granitic and a trachytic, which correspond to the ditroite and foyaite of Brögger.⁵ One or two representatives of Brögger's laurdalite-structure were found, but not in typical development. While the two main structural types shade into one another the foyaitic seems to predominate, or at least there is a strong tendency to foyaitic development.

The ditroites from Salem Neck, Great Haste Island and Mackerel Cove are not very coarse-grained rocks, of dull gray

¹ KIMBALL, Am. Jour. Sci. (2), Vol. XXIX, p. 67, 1860.

² WADSWORTH, Geol. Mag., 1885, p. 209.

³ SEARS, Bull. Essex Inst., Vol. XXIII, 1891.

⁴ ROSENBUSCH, Mikr. Phys., Vol. II, p. 185, 1896.

⁵ BRÖGGER, Zeit. Kryst., Vol. XVI, p. 39, 1890, and also ERUPTGEST, der Krist. geb., Vol. III, p. 165, 1898.

color and granitic structure. The feldspar is white ; nepheline gray or brownish, with occasional yellow or gray cancrinite and blue sodalite which is abundant in certain veins on Salem Neck and elsewhere. Biotite, hornblende and aegirite are common, but are very irregularly distributed. Often they are scattered uniformly through the mass, but again they are rare or else abundant, and any one may predominate to the exclusion of the others. Occasional small brown crystals of zircon are seen, often of some size, but it never rises above the rank of an accessory, so that the name zircon-syenite, which has been applied to these rocks is quite unjustified. Magnetite is not uncommon, sometimes in large grains, and pyrrhotite is seen in one specimen.

In thin section the feldspars, chiefly albite and orthoclase, show less tendency to microperthitic intergrowth than in the granites, though such are not rare. The orthoclase is frequently in Carlsbad twins, and the albite shows twinning lamellæ, but both are found in simple crystals. Microcline, spoken of by Rosenbusch as abundant, is rare in my sections. The nepheline calls for no special comment. While usually interstitial between the feldspars, small, stout prisms are often included in them. Sodalite is rare in the sections. In the rock from Mackerel Cove and from Great Haste Island it occurs decomposed to a dull, fine-grained aggregate (*Spreustein*) interstitial between the feldspars. This decomposition has taken place while the nepheline has remained perfectly fresh. Cancrinite, colorless in thin sections, was observed in the syenite from Salem Neck in small amount, but elsewhere was rare. It was identified by its cleavage and high birefringence.

Perhaps the most common of the ferromagnesian minerals is a deep brown, highly pleochroic biotite, which forms thick plates or stout prisms. An olive-green biotite also occurs on Salem Neck, but is much less common. Hornblende is not very abundant, except in the foyaites of Salem Neck. It is greenish-brown, or a deep olive-green, and highly pleochroic, and much resembles the aegirite. In a few cases it occurs as a border around

aegirite. The pyroxenes are represented by a very pale, greenish-gray aegirite-augite ($c \wedge c = 34^\circ$) and by green aegirite. The former occurs in quantity only in one specimen from Salem Neck with biotite. The ægirite is abundant in many sections, often in those free from biotite. It is clear grass-green, with strong pleochroism: **a** = deep grass-green, **b** = grass-green, **c** = light greenish-yellow. The extinction $c \wedge c$ is about 7° .

Titanite, magnetite, and zircon are rare; apatite occurs in patches, but is not common. No eudialyte was seen. A few grains of a yellow, strongly pleochroic mineral, referred to laavenite, were found.

	I	II	III
SiO ₂ - - -	58.77	59.31	60.39
TiO ₂ - - -	0.31	0.32	....
ZrO ₂ - - -	0.11	....	....
Al ₂ O ₃ - - -	22.64	22.50	22.51
Fe ₂ O ₃ - - -	1.54	1.93	0.42
FeO - - -	1.04	1.40	2.26
MnO - - -	trace	trace	0.08
MgO - - -	0.19	0.17	0.13
CaO - - -	0.74	0.46	0.32
BaO - - -	none	....	....
Na ₂ O - - -	9.62	7.98	8.44
K ₂ O - - -	4.89	4.08	4.77
H ₂ O(110°-) - -	0.07	0.15	....
H ₂ O(110°+)- -	0.90	1.12	0.57
	100.82	99.42	99.95

I Nepheline-Syenite. Salem Neck. H. S. Washington anal.

II Nepheline-Syenite. Great Haste Island. H. S. Washington anal.

III Litchfieldite. Litchfield, Maine. L. G. Eakins anal. BAYLEY, Bull. Geol. Soc. Amer., Vol. III, p. 241, 1892, contains trace of CO₂.

The foyaites show their structure in the hand specimen very clearly, most surfaces exhibiting a multitude of long, glistening cleavage surfaces of feldspar, arranged in parallel position, forming a sort of flow structure. Surfaces in one direction, however, are made up of flat isometric feldspar plates, owing to the tabular development of the crystals parallel to *b* (010). They are clear ash-gray, and not very fine grained. In thin section they

differ from the preceding chiefly in the structure, which is eminently trachytic. The minerals are much the same, and the feldspars differ only in habit.

Two analyses of the nepheline-syenites were made, one of a specimen from Salem Neck west of the Fort, which was collected on the excursion of the A. A. A. S. in August 1898, under the guidance of Mr. Sears; the other of a specimen from Great Haste Island, given me by that gentleman. The former is foyaitic in microstructure, the latter more ditroitite. Both are apparently quite fresh. Analysis III, of litchfieldite, is introduced for comparison.

The two analyses resemble each other very closely, except that the former has more soda and less iron oxides. Compared with nepheline-syenites from other regions, the Salem rocks are notably poorer in lime and magnesia, and rather higher in silica than most. In these respects they correspond closely to the nepheline-syenites of Litchfield, Maine, and Red Hill, New Hampshire, described by Bayley,¹ especially the former. This is an extremely albite-rich type, to which he has given the name of Litchfieldite. Bayley regards the orthoclase as secondary for the most part, but it is to be observed that, even if it owes its present form to secondary processes, it must have existed in the original rock. Although the composition of the ferromagnesian minerals in the Salem rock is not known with certainty, yet a rough estimate may be made of its mineralogical composition. This is given in **Ia**, the composition of the Litchfield rock as calculated by Bayley from good data being given in **IIIa**. It will be seen that there is much similarity between the two.

	Ia	IIIa		Ia	IIIa
Albite - - -	43	46.9	Lepidomelane - - ..		6.9
Orthoclase - -	27	27.0	Biotite, etc. - -	6	...
Nephelite - -	20	17.0	Zircon, Magnetite, etc.	3	...
Cancrinite - -	1	2.0			

Pulaskitic Syenite.—In connection with the nepheline-syenites, and constituting a facies of them, are found rocks which

¹ BAYLEY, Bull. Geol. Soc. Amer., Vol. III, p. 231, 1892.

are either extremely poor in, or quite wanting in, nepheline. These are true syenitic rocks and among my specimens two main varieties may be distinguished. They shade into the preceding group by imperceptible gradations.

The first is found at a quarry on the north shore of Salem Neck, west of the Fort, and is essentially a border facies near the contact with essexite, which crops out close by on the other side of a small hollow. This is typically foyaitic (trachytic) in structure and shows the tabular feldspars and their parallel arrangement. A variety of this, met with farther east near the water's edge, is brownish and porphyritic through the presence of abundant feldspar tables strewn irregularly in a feldspathic groundmass. These syenites resemble the foyaïtes in all essentials, except that nepheline is absent and the feldspars are nearly always micropertthitic. The colored minerals are olive-green hornblende, brown biotite, and green aegirite, all in about the same amount. Magnetite grains and an occasional apatite needle are also found.

This rock corresponds closely, both in evident structure and mineral composition, to the hedrumite of Brögger¹ from the laurdalite region, and which he defines as: "nepheline-poor to nepheline-free syenitic rocks with trachytic structure exactly corresponding to that of the foyaïtes." Since, however, its analysis (I) shows that it is decidedly more acid than Brögger's analysis of hedrumite, it would better be classed with the pulaskites.

The other type of syenite forms coarse-grained masses and veins in the nepheline-syenite, and is best represented by a specimen from Salem Neck given me by Mr. Sears. This shows a coarse-grained mass of pearly, tabular, alkali-feldspar crystals, arranged in radiating groups, with a little aegirite, etc., in black grains and a minute amount of magnetite. Under the microscope the feldspar tables are seen to be micropertthite, though kryptopertthite is also seen, as well as albite alone, showing fine and clear twinning lamellæ. There is possibly a slight admix-

¹ BRÖGGER, *Zeit. Kryst.*, Vol. XVI, p. 40, 1890. It is more fully described later in *Erupt. gest. d. Krist. geb.*, Vol. III, pp. 183 ff., 1897.

ture of the anorthite molecule. The only colored component seen in the sections is a grass-green aegirite, but other ferromagnesian minerals are probably present. The large crystals are well shaped, but have borders of detached aegirite grains which are embedded in the surrounding feldspar. These grains extinguish simultaneously with each other and with the large crystal, forming a sort of pegmatitic zone. The aegirite has been apparently curiously corroded by the magma and the hollows filled with feldspar substance. Nepheline occurs very sparingly in small interstitial spots.

An analysis of this type yielded the results below, in II :

	I	II	III	IV
SiO ₂ - - -	63.71	63.09	64.54	63.71
TiO ₂ - - -	trace	0.45	trace	0.86
ZrO ₂ - - -	....	0.06	....	....
Al ₂ O ₃ - - -	18.30	18.50	18.13	16.59
Fe ₂ O ₃ - - -	2.08	2.90	2.63	2.92
FeO - - -	2.52	1.36	0.97	0.66
MnO - - -	trace	trace	....	0.20
MgO - - -	0.09	0.16	0.67	0.90
CaO - - -	1.18	1.00	0.62	3.11
BaO - - -	....	....	0.42	....
Na ₂ O - - -	6.39	7.25	6.60	8.26
K ₂ O - - -	6.21	5.23	5.99	2.79
H ₂ O(110°—) -	0.09	0.21	....	....
H ₂ O(110°+) -	0.17	0.62	0.31	0.19
P ₂ O ₅ - - -	....	....	trace	....
	100.74	100.83	100.88	100.19

I Pulaskite (hedrumitic). Salem Neck. H. S. WASHINGTON anal.

II Pulaskite. Salem Neck. H. S. WASHINGTON anal.

III Pulaskite. Farrisvand. BRÖGGER. Erupt. gest. Krist. geb. III, 198. 1898.

IV Umptekite. Bank of the Umpjaur. Kola Penin. Finland. ROSENBUSCH. Elemente d. Gesteinslehre. 1898, p. 112. No. 5.

It is decidedly more acid than the normal type, carrying less alumina, a little more lime, and about the same amount of alkalis. It is evidently a rather acid syenite, but its real affinities are uncertain. It bears a resemblance to the umptekite which Ramsay observed on the borders of the nepheline-syenite of Kola, and it is of interest to note that Rosenbusch speaks of

umpteckites occurring at Curtis' Point, Beverly, and other localities of the Massachusetts region, and also refers the nepheline-syenite of Red Hill, N. H., to this type.¹ The umpteckites, however, are typically soda-hornblende rocks, and markedly higher in lime and magnesia, as seen in analysis IV. They certainly show greater analogies with the pulaskites as defined by Brögger: "Nepheline-poor to nepheline-free rocks, also quartz-free or very poor in quartz, poor in dark minerals and with eugranitic structure, in which a development of the feldspars with rectangular or long rectangular sections predominates." It is of interest to observe also the affinity with the albite-rich litchfieldite. A rough calculation of the analysis II gives albite about 58.5 per cent., orthoclase about 31.5, anorthite about 2, and the rest (8 per cent.) colored minerals and magnetite. This rock, then, may be called a pulaskite, or rather a pulaskitic phase of the nepheline-syenite. It must be borne in mind, however, that both this and the hedrumite are only facies of the main foyaitic mass, and not independent rock bodies, at least so far as is yet known.

Orbicular syenite.—A small but interesting type of syenites is found near Bass Rock, Gloucester, and also, according to Mr. Sears, at Salem Neck, Beverly, and on the Manchester Shore, the development being in all cases quite local. Near Bass Rock, the only locality examined by me, it occurs as rounded inclosures in an outcrop of granite, apparently in place, together with similar masses of a dark, coarse-grained dioritic rock, which will be described later. A narrow compound dike of aplite cuts the granite and its inclosures. Of the occurrence of Mr. Sears' specimens I have no data at hand. The syenites are fine-grained and compact, with a groundmass of a light-gray color. Scattered through this are phenocrysts of black hornblende some 0.5 c.m. long, each hornblende being surrounded by a narrow zone of white, finely granular feldspar. These small areas of black with white borders give a peculiar orbicular appearance to the specimen.

¹ Cf. ROSENBUSCH, *Elemente d. Gesteinslehre*. 1898, pp. 113.

Under the microscope the groundmass is seen to be finely granitic in structure, and to be composed largely of alkali feldspar in xenomorphic grains, microperthite being rare, with only an occasional plagioclase grain. There are also present, somewhat abundantly, small, clear, rectangular sections of orthoclase. A little quartz occurs, especially as small interstitial grains. Irregular anhedral of colorless or very pale greenish-gray diopside are scattered through the groundmass. These are often surrounded by a zone of green or bluish-green pleochroic hornblende, which does not seem to be secondary. Magnetite grains, often surrounded by an amphibole halo, are not uncommon, and small apatite needles are met with.

The large black spots consist essentially of an olive-green, slightly pleochroic, hornblende. These hornblende areas are not continuous, but are made up of more or less rounded spots of hornblende, between which lies a granitic mesostasis of feldspar grains like the groundmass. The small hornblende spots in each area have their cleavage cracks parallel and extinguish simultaneously, so that the structure is micropoikilitic. The white borders are of granular feldspar, free from pyroxene, in which the small rectangular orthoclase sections seem to be more common. They pass insensibly into the surrounding groundmass.

A specimen given me by Mr. Sears from Salem Neck (?) is similar, but the structure of the groundmass is more trachytic, the pyroxene is largely replaced by dark green biotite, and the hornblende phenocrysts are much darker in color. The orbicular spots are quite ophitic in structure, owing to the tabular development of the feldspars. No analysis of these rocks has yet been made.

HENRY S. WASHINGTON.

(To be Continued)